DISSOLUTION OF METASTABLE CARBONATE MINERALS: EFFECTS OF PHYSICAL MIXING AND POTENTIAL AS A BUFFER AGAINST RISING ATMOSPHERIC CO_2 IN CORAL REEF ECOSYSTEMS

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Abstract

The atmospheric CO_2 record from the Mauna Loa observatory, Hawaii, shows a dramatic increase of atmospheric CO_2 concentrations of 35% since 1850. This rise, attributed mainly to human activities is expected to persist during the 21st century and reach an atmospheric CO_2 concentration close to 700 ppmv by the end of the 21st century (Mackenzie, 1995). Increasing atmospheric CO_2 will lead to increased invasion of CO_2 into the surface ocean and will subsequently cause a decrease in pH and surface water saturation state with respect to $CaCO_3$. Consequently, calcareous organisms such as corals may have difficulty calcifying (Gattuso et al., 1998, 1999; Kleypas et al., 1999, 2001; Andersson et al., 2003). However, an alternative hypothesis, sometimes referred to as the Magnesian Salvation Theory, suggests that no changes or negative effects will be observed on coral reef ecosystems because dissolution of metastable carbonate minerals will restore any changes in carbonate saturation state and pH owing to increasing atmospheric CO_2 (Halley and Yates, 2000; Barnes and Cuff, 2000).

In a previous study, Andersson et al (2003) investigated whether such dissolution and buffering could occur within the shallow-water ocean environment on a global scale. The results showed that metastable carbonates could dissolve in the future owing to increased invasion of atmospheric CO_2, but the surface water of the global shallow-water ocean environment will not accumulate sufficient alkalinity to buffer pH or carbonate saturation state.

The problem of whether dissolution by metastable carbonate phases can buffer the overlying water column of the coral reef region is dependent on the extent of carbonate

dissolution and the rates of physical mixing with the open ocean (Andersson et al., 2003).

Physical mixing processes and pore water chemistry may vary greatly among different environments. It is therefore expected that a regional model of the global coral reef ecosystem could demonstrate results different from those obtained with the idealized average environmental setting of a global shallow-water ocean model.

The model results shows that the carbonate buffering effect owing to dissolution of metastable carbonate minerals will not be sufficient to restore any changes in surface water calcium carbonate saturation state of the global coral reef environment. However, the extent of the buffering effect is predicted to vary significantly among different coral reef ecosystems. The CROCM scenarios predicted a decrease in biogenic carbonate production of 11 to 43% during the 21st century in coral reef environments, depending on the intensity of water exchange between the coral reef ecosystem and the open ocean. The higher calcium carbonate reduction rates are associated with the coral reef ecosystem that exhibit relatively high exchange rates between the waters bathing the reef and the open ocean, such as barrier reefs and fringing reefs. Coral reef ecosystems with relatively poor water exchange characteristics, such as atoll lagoons, are expected to be less affected as the dissolution of metastable carbonate minerals might maintain the surface water carbonate saturation states at higher levels because the relatively long water residence times allow sufficient alkalinity to accumulate. Consequently, increasing atmospheric CO_2 concentration will have a significant impact on the maintenance, expansion and accretion of reef-building ecosystems, as an important decrease in future calcification rates is predicted by the CROCM calculations.